SPECIFICATION

TITLE OF INVENTION

APPARATUS FOR SPATIAL AND TEMPORAL CONTROL OF TEMPERATURE ON A SUBSTRATE

FIELD OF THE INVENTION

[0001] The present invention relates to substrate supports. More particularly, the present invention relates to a method and apparatus for achieving uniform temperature distribution on a substrate during plasma processing.

BACKGROUND OF THE INVENTION

[0002] A typical plasma etching apparatus comprises a reactor in which there is a chamber through which reactive gas or gases flow. Within the chamber, the gases are ionized into a plasma, typically by radio frequency energy. The highly reactive ions of the plasma are able to react with material, such as a polymer mask on a surface of a semiconductor wafer being processed into integrated circuits (IC's). Prior to etching, the wafer is placed into the chamber and held in proper position by a chuck or holder which exposes a top surface of the wafer to the plasma. There are several types of chucks (also sometimes called susceptors) known in the art. The chuck provides an isothermal surface and serves as a heat sink for the wafer. In one type, a semiconductor wafer is held in place for etching by mechanical clamping means. In another type of chuck, a

semiconductor wafer is held in place by electrostatic force generated by an electric field between the chuck and wafer. The present invention is applicable to both types of chucks.

[0003] In a typical plasma etching operation, the reactive ions of the plasma chemically react with portions of material on a face of the semiconductor wafer. Some processes cause some degree of heating of the wafer, but most of the heating is caused by the plasma. The chemical reaction rate between the materials in the plasma and the wafer material, on the other hand, is accelerated to some degree by the temperature rise of the wafer. Local wafer temperature and rate of chemical reaction at each microscopic point on the wafer are related to an extent that harmful unevenness in etching of material over a face of the wafer can easily result if the temperature of the wafer across its area varies too much. In most cases, it is highly desirable that etching be uniform to a nearly perfect degree since otherwise the Integrated Circuit devices (ICs) being fabricated will have electronic characteristics that deviate from the norm more than is desirable. Furthermore, with each increase in the size of wafer diameter, the problem of ensuring uniformity of each batch of ICs from larger and larger wafers becomes more difficult. In some other cases, it would be desirable to be able to control the surface temperature of the wafer to obtain a custom profile.

[0004] The problem of temperature rise of a wafer during reactive ion etching (RIE) is well known, and various attempts in the past to control the temperature of a wafer during RIE have been tried. FIG. 1 illustrates one way to control wafer

temperature during RIE. An inert coolant gas (such as helium or argon) is admitted at a single pressure within a single thin space 102 between the bottom of the wafer 104 and the top of the chuck 106 which holds the wafer 104. This approach is referred to as backside gas cooling.

[0005] There is generally no o-ring or other edge seal at the chuck perimeter except for a smooth sealing land extending from about 1 to 5 mm at the outer edge of the chuck 106 in order to reduce coolant leakage. Inevitably, without any elastomer seal, there is significant and progressive pressure loss across the sealing land, such that the edge of the wafer 104 is inadequately cooled. The heat generated near the edge of the wafer 104 must therefore flow significantly radially inward before it can effectively be conducted away to the chuck. The arrows 106 on top of the wafer 104 illustrate the incoming flux heating the wafer 104. The flow of the heat in the wafer 104 is illustrated with the arrows 110. This explains why the edge zone of the chuck always tends to be hotter than the rest of the surface. FIG. 2 illustrates a typical temperature distribution on the wafer 104. The pressure loss at the peripheral portions of the wafer 104 causes the wafer 104 to be much hotter at the peripheral portions.

[0006] One way of dealing with the need for zone cooling is to vary the surface roughness or to cut a relief pattern to effectively change the local contact area. Such a scheme can be used without backside coolant gas at all, in which case the contact area, surface roughness, and clamp force determine the heat transfer. However the local contact area can only be adjusted by re-machining the chuck. Another way of dealing

with the need for zone cooling is to use coolant gas whose pressure is varied to increase and fine tune thermal transport. However the relief pattern is still substantially fixed. By dividing the surface of the chuck into different zones, with or without small sealing lands as dividers, and supplying separate cooling gasses to each zone, a greater degree of independent spatial control may be achieved. The gas supply to each zone may have different composition or be set to a different pressure, thus varying the thermal conduction. Each zone's operating conditions may be set under recipe control, or even dynamically stabilized during each process step. Such schemes depend on redistributing the incoming heat flux from the plasma and driving it into different regions. This is relatively effective at high power flux but will only give small temperature differentials at lower power flux. For instance, with about 3 to 6W per cm^2 of uniform flux and about 3mm sealing land, it is possible to get center to edge thermal gradients that lead to a 10°C to 30°C temperature increase near the wafer periphery. Thermal gradients of this magnitude can be very effective as a process control parameter. For example, radial variations in plasma density or asymmetries in a reactor layout, which can affect critical process performance metrics, are counteracted with an appropriate substrate temperature pattern. However, some processes may run at low power, for instance poly gate processes, may have a flux of only 0.2W per cm^2. Unless the average conduction is made extremely low, which is very difficult to control and tends to result in inadequate overall cooling, then there will be only a very small differential of typically less than 5°C.

[0007] Accordingly, a need exists for a method and apparatus for controlling the temperature of semiconductor wafers during reactive ion etching and similar processes

without requiring significant plasma heat flux. A primary purpose of the present invention is to solve these needs and provide further, related advantages.

BRIEF DESCRIPTION OF THE INVENTION

[0008] An apparatus for control of a temperature of a substrate has a temperature-controlled base, a heater, a metal plate, a layer of dielectric material. The heater is thermally coupled to an underside of the metal plate while being electrically insulated from the metal plate. The heater can be composed of multiple, independently controlled regions to impart a spatially resolved thermal pattern. Temperature feedback for each heater region is connected to appropriate power supplies, which controls their thermal output. A first layer of adhesive material bonds the metal plate and the heater to the top surface of the temperature controlled base; the adhesive possesses physical properties that allow the thermal pattern to be maintained under varying external process conditions. A second layer of adhesive material bonds the layer of dielectric material to a top surface of the metal plate. The layer of dielectric material forms an electrostatic clamping mechanism and supports the substrate. High voltage is connected to the dielectric portion to accomplish electrostatic clamping of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings, which are incorporated into and constitute a part of this specification, illustrate one or more embodiments of the present invention and, together with the detailed description, serve to explain the principles and implementations of the invention.

[0010] In the drawings:

FIG. 1 is a schematic elevational diagram of a support holding a wafer under process in accordance with the prior art;

FIG. 2 is a plot illustrating the temperature of a wafer and the pressure of a coolant in the apparatus of FIG. 1 in accordance with the prior art;

FIG. 3 is a diagram schematically illustrating a processing chamber having a base in accordance with one embodiment of the present invention.

FIG. 4 is a table illustrating the relationship between surface temperature range and parallelism of the layers in accordance with one embodiment of the present invention.

FIG. 5 is a diagram schematically illustrating the apparatus surface temperature control scheme in accordance with one embodiment of the present invention.

FIG. 6 is a diagram schematically illustrating a processing chamber having a base in accordance with another embodiment of the present invention.

FIG. 7 is a diagram schematically illustrating a processing chamber having a base in accordance with yet another embodiment of the present invention.

FIG. 8 is a diagram schematically illustrating the apparatus surface temperature control scheme in accordance yet another embodiment of the present invention.

FIG. 9 is a diagram schematically illustrating a processing chamber having a base in accordance with yet another embodiment of the present invention.

FIG. 10 is a diagram schematically illustrating a cross-sectional view of an electrical connector in accordance with one embodiment of the present invention.

FIG. 11 is a flow diagram schematically illustrating a method for spatially and temporally controlling the temperature on a substrate during processing in accordance with one embodiment of the present invention.

FIGS. 12A, 12B, 12C are diagrams schematically illustrating a cross-sectional view of the apparatus being built in accordance with one embodiment of the present invention.

FIG. 13 is a flow diagram illustrating a method for spatially and temporally controlling the temperature on a substrate during processing in accordance with another embodiment of the present invention.

FIGS. 14A, 14B, 14C, 14D are diagrams schematically illustrating a cross-sectional view of the apparatus being built in accordance with another embodiment of the present invention.

FIG. 15 is a flow diagram schematically illustrating a method for electrically connecting a power supply to a heater and an electrostatic electrode in a base in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION

[0011] Embodiments of the present invention are described herein in the context of a support for a substrate. Those of ordinary skill in the art will realize that the following detailed description of the present invention is illustrative only and is not intended to be in any way limiting. Other embodiments of the present invention will readily suggest themselves to such skilled persons having the benefit of this disclosure. Reference will now be made in detail to implementations of the present invention as illustrated in the accompanying drawings. The same reference indicators will be used throughout the drawings and the following detailed description to refer to the same or like parts.

[0012] In the interest of clarity, not all of the routine features of the implementations described herein are shown and described. It will, of course, be appreciated that in the development of any such actual implementation, numerous implementation-specific decisions must be made in order to achieve the developer's specific goals, such as compliance with application- and business-related constraints, and that these specific goals will vary from one implementation to another and from one developer to another. Moreover, it will be appreciated that such a development effort might be complex and time-consuming, but would nevertheless be a routine undertaking of engineering for those of ordinary skill in the art having the benefit of this disclosure.

[0013] The tunable electrostatic chuck of the present invention is an apparatus used for controlling the processing temperature of a substrate in plasma enhanced and

thermally enhanced reactions. The apparatus allows for a fixed substrate temperature to be maintained under varying amounts of external heat load from the process but also for deliberate change of temperature as a function of time. The apparatus also allows for spatially resolved temperature signatures to be imparted and maintained on the substrate during the process.

[0014] The tunable electrostatic chuck balances energy from heat sources located within the apparatus in response to the thermal energy input of the external process, thereby maintaining a desired surface temperature on the apparatus. Under static thermodynamic conditions, increasing the thermal energy from these heater sources will raise the surface temperature; decreasing the thermal energy will lower the surface temperature. Consequently, the control of the thermal energy in this way provides for temporal modification of the surface temperature. In addition, a spatially resolved heat source, i.e. a heat source with varied thermal energy as a function of location, will provide the capability of spatial temperature control. By controlling the surface temperature of the apparatus, the substrate that is well thermally coupled to the surface of the apparatus will also benefit from the same temperature control used by the apparatus.

[0015] The substrate temperature significantly affects the semiconductor process. The ability to provide temporal and spatial control of the surface temperature of the semiconductor represents a very powerful feature for device fabrication. However, the heat transfer properties of the apparatus should be spatially uniform. Failure to accomplish this heat transfer property may result in undesirable temperature signatures

that cannot be corrected without employing very expensive and impractical control schemes (e.g., a very high density of individual control loops).

[0016] FIG. 3 illustrates a chamber 302 having an apparatus 304 for temporal and spatial control of the temperature of a substrate 306. The apparatus 304 comprises a temperature-controlled base 308, a layer of adhesive material 310, a heater film 312, a metal plate 314, and a layer of dielectric material 316.

[0017] The base 308 may include an actively cooled metal support member that is fabricated with length and width dimensions approximating those of substrate 306. A cooling media 319 maintains the temperature of base 308. The top surface of base 308 is machined to a high degree of flatness. In one embodiment used with 200mm or 300mm silicon wafer, the variation may be less than 0.0003" throughout the top surface of base 308.

[0018] The top and bottom surfaces of metal plate 314 are made of a high degree of flatness (within 0.0005" surface variation) and parallelism (within 0.0005" surface variation). The thickness of metal plate 314 is sufficient to adequately transfers the spatial pattern of a thermal heat source (such as the heater film 312) directly underneath and in intimate contact with the metal plate 314. In one embodiment, metal plate 314 may include an aluminum plate having a thickness of about 0.040".

[0019] Heater 312 may be a thin and flexible polyimide heater film bonded to the bottom side of metal plate 314. Heater 312 may be constructed of multiple resistive elements, with a pattern layout designed to accomplish spatial temperature control on the surface of the finished assembly. To prevent any potential electrical problems, the heating elements are electrically insulated from metal plate 314. Flexible heater 312 is in intimate contact with metal plate 314. In one embodiment, heater 312 includes a polyimide heater film having a thickness of about 0.010" with a surface variation within 0.0005".

[0020] Both metal plate 314 and heater 312 are attached to base 308 using a uniformly deposited, mechanically flexible adhesive 310. Metal plate 314 and base 308 are separated by this layer of adhesive material 310 with a high degree of parallelism. The layer of adhesive material 310 has height dimension and thermal conductivity that defines an appropriate heat transfer between heating elements 312 and the external process. The heat transfer coefficient may be determined by the relative power levels employed by the heating elements and external process. In one embodiment, the layer of adhesive material 310 may include a silicone bond layer having a thermal transfer coefficient of about 0.17 W/m-°K to about 0.51 W/m-°K. In one embodiment, the thickness of the layer of adhesive material 310 may range from about 0.013" to about 0.040" with thickness variation (i.e., parallelism) within 0.001". The importance of the thickness variation requirement is illustrated by the graph in FIG. 4. For a fixed heat transfer coefficient (defined by nominal adhesive layer thickness and adhesive layer

thermal conductivity), the resulting surface temperature non-uniformity will increase with increasing parallelism. To avoid problems with device fabrication resulting from unwanted thermal non-uniformities, the adhesive layer thickness variation must be minimized, thereby implying an apparatus whose design can achieve this requirement.

[0021] Returning to FIG. 3, a thin layer of dielectric material 316 may be deposited (via CVD, spray-coating, etc...) on the top surface of metal plate 314 to form an electrostatic clamping mechanism. Those of ordinary skills in the art will recognize that any conventionally used material with high field breakdown strength and chemical resistance to the external process can be employed (e.g., aluminum oxide, aluminum nitride, yttrium oxide, etc.). The thickness and surface condition of the layer of dielectric material 316 may be defined so that the holding force and heat transfer characteristics impart the spatial temperature pattern of the metal plate 314 to the substrate 306. In one embodiment, the layer of dielectric material 316 has a thickness of about 0.002" with a top surface variation within 0.001".

[0022] Separately insulated electrical connections 322 and 324 may be made to the heating elements of heater 312, and metal plate 314 (which is coupled to the dielectric material 316) so as to provide control of these features with independent power supplies respectively Electrostatic Chuck (ESC) power supply 318 and heater power supply 320. An example of the insulated electrical connections are illustrated and later described in FIG. 10.

[0023] Regional control of surface temperature is accomplished with one or more measurement probes that contact the metal plate through penetrations 508 in the underlying layers, shown in FIG. 5. The probe 502 is part of a feedback loop 506 for control of one or more heating elements 510; the probe output can be passed through a filtering scheme 504, if necessary, to eliminate any radio frequency noise on the measurement signal should the apparatus be operated in an environment containing radio frequency power. Given the small height dimension of the metal plate previously defined--necessary for adequate transfer of heater thermal pattern to the surface of the apparatus--a suitably accurate estimate of the surface temperature can thereby be acquired.

[0024] FIG. 6 illustrates another embodiment of a chamber 602 having an apparatus 604 for temporal and spatial control of the temperature of a substrate 606. The apparatus 604 comprises a temperature controlled base 608, a layer of adhesive material 610, a heater film 612, a ceramic plate 614, and a layer of dielectric material 616. A cooling media 519 maintains the temperature of base 608. A first power supply 620 supplies electrical power to heater 612 via electrical connector 624. A second power supply 618 supplies electrical power to the layer of dielectric material 616 via electrical connector 622. Base 608, layer of adhesive material 610, heater 612, and layer of dielectric material 616 were previously described in FIG. 3. An example of the electrical connections is also illustrated and later described in FIG. 10. Heater 612 is deposited to the underside of a ceramic plate 614 instead of metal plates 314, as described in FIG. 3. Ceramic plate 614 may include, for example, aluminum nitride or aluminum oxide. The

thickness of ceramic plate 614 is such that it adequately transfers the special pattern of the thermal heat source (heater 612) directly underneath and in intimate contact with ceramic plate 614. Heater 612 does not have to be electrically insulated from the ceramic plate 614. In one embodiment, base 608 has a top surface variation of about 0.0003". The thickness of layer of adhesive material 610 may range from about 0.013" to about 0.040" with a top and bottom surface variation within 0.0003" and a parallelism (top surface variation – bottom surface variation) of within 0.001". Heater 612 has a thickness of about 0.010" with a bottom surface variation within 0.0005". Ceramic plate 614 has a thickness of about 0.040" with top surface variation within 0.0005" and a bottom surface variation within 0.0002". Layer of dielectric material 616 (which is coated on ceramic plate 614) has a thickness of about 0.002" with a top surface variation within 0.001". The layer of dielectric material 616 may be deposited (via CVD, spray-coating, etc...) on the surface of heater plate 614 (made of metal or ceramic). A conductive material of suitable properties would also need to be deposited to form a clampling electrode.

[0025] FIG. 7 illustrates another embodiment of a chamber 702 having an apparatus 704 for temporal and spatial control of the temperature of a substrate 706. The apparatus 704 comprises a temperature controlled base 708, a layer of adhesive material 710, a heater film 712, a ceramic or metal plate 714, a layer of adhesive material 715, and a layer of dielectric material 716. A cooling media 719 maintains the temperature of the base 708. A first power supply 720 supplies electrical power to the heater 712 via electrical connector 724. A second power supply 718 supplies electrical power to the

layer of dielectric material 716 via electrical connector 722. The base 708, the layers of adhesive material 710, 715, and the heater 712 were previously described in FIGS. 3 and 6. The heater 712 is deposited to the underside of a ceramic or metal plate 1414. The dielectric layer 716 is a separate component containing a conductive electrode and appropriate insulating films to form an electrostatic clamping mechanism, may have a thickness of about 0.040", and may have a top and bottom surface variation within 0.001". The separate and pre-fabricated layer of dielectric material 716 is attached to the metal or ceramic plate 714 using a layer of adhesive material 715. An example of the electrical connections is also illustrated and described in FIG. 10.

[0026] Regional control of surface temperature is accomplished with one or more measurement probes 802 that contact the dielectric plate through penetrations 808 in the underlying layers, shown in FIG. 8. The probe 802 is part of a feedback loop 806 for control of one or more heating elements 810; the probe output can be passed through a filtering scheme 804, if necessary, to eliminate any radio frequency noise on the measurement signal should the apparatus be operated in an environment containing radio frequency power. Given the small height dimension of the dielectric layer previously defined--necessary for adequate transfer of heater thermal pattern to the surface of the apparatus--a suitably accurate estimate of the surface temperature can thereby be acquired.

[0027] FIG. 9 illustrates another embodiment of a chamber 902 having an apparatus 904 for temporal and spatial control of the temperature of a substrate 906 in

which the layer of adhesive material 910 includes a top layer of bonding material 926, a solid plate 928, and a bottom layer of bonding material 930. The apparatus 904 comprises a temperature-controlled base 908, a layer of adhesive material 910, a heater film 912, a metal or ceramic plate 914, a layer of adhesive material 913, and a layer of dielectric material 916. In one embodiment, base 908 has a top surface variation within 0.0003". Heater film 912 may have a thickness of about 0.010" with a bottom surface variation within 0.0005". Metal or ceramic plate 914 may have a thickness of about 0.040" with a top surface variation within 0.0005" and a bottom surface variation within 0.0002". Layer of adhesive material 913 may have a thickness of about 0.004". Layer of dielectric material 916 may have a thickness of about 0.040" with a top and bottom surface variation within 0.001".

[0028] A cooling media 919 maintains the temperature of base 908 constant. A heater power supply 920 supplies electrical power to heater 912 via electrical connector 924. A ESC power supply 918 supplies electrical power to the metal plate 913 or to dielectric material 916 via electrical connector 922. Base 908, metal or ceramic plate 914, heater 912, layer of adhesive material 913, and layer of dielectric material 916 were previously described. An example of the electrical connections is also illustrated and later described in FIG. 10.

[0029] The layer of dielectric material 916 may be deposited (via CVD, spray-coating, etc...) on the surface of heater plate 914 (made of metal or ceramic). If a metal plate is used, this same plate may be employed for the clamp electrode. If a ceramic plate

is used, then a conductive material of suitable properties would also need to be deposited to form a clampling electrode.

[0030] Solid plate 928 sandwich between top layer of adhesive material 926 and bottom layer of adhesive material 930 is made of a plastic material (such as vespel or torlon). In one embodiment, the thickness of solid plate 928 may range from about 0.006" to about 0.020" with a top and bottom surface variation (parallelism) within 0.001". The thermal conductivity of solid plate 928 may be about 0.17 W/mK. The thermal conductivity of solid plate 928 may be substantially similar to the thermal conductivity of the top and bottom layer of adhesive material 926 and 930. The thermal conductivity of solid plate 928 may be determined by the relative power levels employed by heating elements 912 and external process. The top layer of adhesive material 926 may have a thickness of about 0.004" with a surface variation within 0.0005". The bottom layer of adhesive material 930 may have a thickness ranging from about 0.006" to about 0.020" with a top and bottom surface variation (parallelism) within 0.001". The bottom surface of solid plate 928 is thus attached to base 908 with mechanically flexible adhesive 930. The top surface of solid plate 928 is thus attached to heater 912 and metal or ceramic plate 914 with mechanically flexible adhesive 926. In another embodiment, the top surface of solid plate 928 may be machined to a surface variation within 0.0005".

[0031] FIG. 10 illustrates a cross-sectional view of an electrical connector 1000 supplying electrical power to a layer of dielectric material (Electrostatic Chuck - ESC) 1002. A pin assembly 1018 comprises a socket 1014, a spring-loaded pin 1010, and a

plastic insulator 1012. The ESC power supply (not shown) is electrically coupled to the pin holder/socket 1014 forming the base of the vertical spring-loaded pin 1010. The top end of the pin 1010 comes into electrical contact with a bottom surface of the layer of dielectric material 1002. The plastic insulator 1012 forms a shaft enclosing the socket 1014 and partially enclosing the spring loaded pin 1010. The top end tip of the spring-loaded pin 1010 vertically protrudes out of the plastic insulator 1012. A portion of the heater layer 1004, the adhesive layer 1006, and the base 1008 form a contiguous cavity 1020 in which the pin assembly 1018 resides.

[0032] A non-electrically conductive bushing 1016 encloses a portion of the top end of the pin 1010 partially including a top end of the plastic insulator 1012. The top part of the bushing 1016 is coupled to the heater layer 1004 with a bonding material 1022 such as silicone adhesive. The bushing 1016 minimizes any anomalous thermal effects caused by the physical contact between the dielectric material 1002 and the top end of the pin 1010. The dielectric material 1002 is heated by the heater 1004. The cooled base 1008 surrounds the pin assembly 1018. The bushing 1016 minimizes the amount of heat drawn from the dielectric material 1002 towards the base 1008 via the pin assembly 1018. The cavity 1020 is large enough to provide added space insulation between the walls of the base 1008 and the outer surface of the plastic insulator 1012.

[0033] FIG. 11 illustrates a flow diagram of a method for controlling the temporal and spatial temperature of a substrate. At 1102, a metal plate is fabricated with length and width dimensions substantially equal to the base. The top and bottom surfaces of the

metal plate are made of a high degree of flatness and parallelism, for example, within 0.005" surface variation. In another embodiment, a ceramic plate may be substituted for the metal plate.

[0034] At 1104, a heater is bonded to an underside of the metal plate. The heater may include a thin and flexible heater film bonded to the bottom side of the metal plate. The heater may also include multiple resistive elements, with a pattern layout designed to accomplish spatial temperature control on the surface of the finished assembly. For example, regional thermal zone may be defined by one or more resistive elements; the heater may include elements defining a radially outer region and a radially inner region. To prevent any potential electrical problems, the heating elements are electrically insulated from the metal plate. The heater is in intimate thermal contact with the metal plate.

[0035] Before attaching the heater and metal plate assembly to a base. At 1106, the top surface of the base is machined down to a high degree of flatness, for example, within 0.0003" surface variation. At 1108, the heater and metal plate assembly are attached to the top surface of the base with a layer of adhesive material.

[0036] In accordance with another embodiment, at 1110, the metal plate may be further machined down after attachment to the base to provide a high degree of flatness. In one embodiment, the top surface variation of the metal plate after machining is within 0.0005".

[0037] At 1112, a thin layer of dielectric material 316 may be deposited on the top surface of the metal plate to form an electrostatic clamping mechanism. Those of ordinary skill in the art will now recognize that any conventionally used material with high field breakdown strength and chemical resistance to the external process can be used for dielectric material 316 (e.g., aluminum oxide, aluminum nitride, yttrium oxide, etc.). In accordance with another embodiment, the dielectric material may pre-fabricated and attached to the top surface of the metal plate with a layer of adhesive material.

[0038] At 1114, separately insulated electrical connections may be made to the heating elements of the heater and the metal plate (which is coupled to the dielectric material) so as to provide control of these features with independent power supplies. The electrical connection may be accomplished using the electrical connector previously described illustrated in FIG. 10.

[0039] FIGS. 12A, 12B, and 12C illustrate the method described in the flow diagram of FIG. 11. FIG. 12A illustrates a metal plate 1202 and the attached heater 1204 assembly being bonded to a base 1206 using a layer of adhesive material 1208 as previously described at 1108. FIG. 12B illustrates the top surface of the metal plate 1202 being machine down a height of about 0.040" with a top surface variation within 0.0005" after being attached to base 1206. FIG. 12C illustrates a layer of dielectric material 1210 being attached to the top surface of metal plate 1202 with a layer of silicone bonding material 1212. Alternatively, the layer of dielectric material 1210 may be applied

directly on the metal plate 1202, using conventional deposition techniques, thereby eliminating the silicone bonding material 1212.

[0040] FIG. 13 illustrates a flow diagram of a method for controlling the temporal and spatial temperature of a substrate. At 1302, a metal plate is fabricated in a similar manner as previously described at 1102 in FIG. 11. At 1304, a heater is bonded to an underside of the metal plate in a similar manner as previously described at 1104 in FIG. 11.

[0041] At 1306, the bottom surface of a solid plate such as a plastic plate is attached to the top surface of a base with a layer of adhesive material. At 1308, the top surface of the plastic plate is machine down to improve the degree of flatness and parallelism. In one embodiment, the solid plate may have a thickness ranging from about 0.006" to about 0.020" with a surface variation within 0.0005".

[0042] At 1310, the metal plate and heater assembly is attached to the top surface of the plastic plate with a layer of adhesive material. Alternatively, the layer of dielectric material may be applied directly on the metal plate, using conventional deposition techniques, thereby eliminating the silicone bonding material.

[0043] At 1312, the top surface of the metal plate may also be machined down after attachment to the base. This was previously described at 1110 in FIG. 11.

[0044] At 1314, the layer of dielectric material (ESC ceramic) is attached to the top surface of the metal plate with a layer of adhesive material. This was previously described at 1112 in FIG. 11.

[0045] At 1316, separately insulated electrical connections may be made to the heating elements of the heater and the metal plate (which is coupled to the dielectric material) so as to provide control of these features with independent power supplies. This was previously described at 1114 in FIG. 11. The electrical connection may be accomplished using the electrical connector previously described and illustrated in FIG. 10.

[0046] FIGS. 14A, 14B, 14C, and 14D illustrate the method described in the flow diagram of FIG. 13. FIG. 14A illustrates a plastic plate 1402 being bonded to a base 1404 using a layer of adhesive material 1406 corresponding to 1306 in FIG. 13. FIG. 14B illustrates the top surface of the plastic plate 1402 being machined down to a height ranging from about 0.006" to about 0.020" after being attached to the base 1404 so as to achieve a top surface variation within 0.0005". FIG. 14C illustrates a metal plate 1408 and heater 1410 assembly being attached to the top surface of the plastic plate 1402 with a layer of adhesive material 1412 corresponding to 1310 in FIG. 13. FIG. 14D illustrates the top surface of the metal plate 1408 being machined down to a thickness of about 0.040" with a top surface variation of about 0.0005". The layer of dielectric material 1414 is attached to the top surface of the metal plate 1408 with a layer of adhesive material 1416 corresponding to 1314 in FIG. 13.

[0047] FIG. 15 illustrates a method for electrically connecting an electrical terminal of the electrostatic clamp of a wafer support having a base, a bonding layer, a heater and a metal plate. At 1502, the non-electrically conductive bushing is attached to the heater at the location defined by one of the electrostatic clamp's electrical terminations. At 1504, the spring-loaded pin is disposed within an insulating sleeve that exposes the tip of the pin. At 1506, the pin with insulating sleeve is disposed in a cavity formed by the base, bonding layer, heater and metal plate, whereby the top portion of the sleeve overlaps the bottom portion of the bushing. At 1508, a top end of the electrical connector including a vertical spring loaded pin contacts with a bottom surface of the electrostatic clamp terminal.

[0048] While embodiments and applications of this invention have been shown and described, it would be apparent to those skilled in the art having the benefit of this disclosure that many more modifications than mentioned above are possible without departing from the inventive concepts herein. The invention, therefore, is not to be restricted except in the spirit of the appended claims.

CLAIMS

What is claimed is:

1. An apparatus for control of a temperature of a substrate comprising:

a temperature-controlled base having a top surface;

a metal plate having a heater thermally coupled to an underside of the metal plate, the heater electrically insulated from said metal plate;

a first layer of adhesive bonding said metal plate and said heater to the top surface of said temperature-controlled base; and

a layer of dielectric material bonded to a top surface of said metal plate with a second layer of adhesive, the layer of dielectric material forming an electrostatic clamping mechanism for supporting the substrate.

2. The apparatus of claim 1 wherein the top surface of said temperature-controlled base is flat to within about 0.0005".

3. The apparatus of claim 1 wherein a surface dimension of said metal plate is substantially similar to the surface dimension of said temperature-controlled base.

4. The apparatus of claim 1 wherein said metal plate also has a bottom surface, the top and bottom surfaces being substantially parallel to each other to within about 0.0005".

5. The apparatus of claim 1 wherein said heater includes a thin and flexible film.

6. The apparatus of claim 1 wherein said heater includes one or more resistive heating elements.

7. The apparatus of claim 6 wherein said resistive heating elements form a pattern layout on said metal plate.

8. The apparatus of claim 1 wherein said adhesive layer includes a uniformly deposited mechanically flexible thermal insulator layer.

9. The apparatus of claim 1 wherein said adhesive layer includes a solid plate.

10. The apparatus of claim 9 wherein said solid plate includes a top and bottom surface, said top and bottom surface being substantially parallel to each other to within about 0.001".

11. The apparatus of claim 9 wherein a thermal conductivity of said solid plate is based on the relative power levels employed by said heater and an external process.

12. The apparatus of claim 9 wherein said bottom surface of said solid plate is bonded to said top surface of said base with a mechanically flexible adhesive having a substantially high thermal conductivity.

13. The apparatus of claim 9 wherein said top surface of said solid plate is bonded to said underside of said metal plate with a mechanically flexible adhesive having a substantially high thermal conductivity.

14. The apparatus of claim 1 further comprising an electrical connector having:

a vertical spring loaded pin having a top end in contact with a bottom surface of the layer of dielectric material, said vertical spring loaded pin disposed in a cavity of said base, said first layer of adhesive layer, and said heater; and

a bushing enclosing a portion of said top end of said pin, said bushing thermally coupled only to said heater and being non-electrically conductive.

15. The apparatus of claim 14 further comprising a socket holding a bottom end of said pin.

16. The apparatus of claim 15 further comprising a plastic insulator cover covering said socket and a portion of said pin, exposing said top end of said pin.

17. The apparatus of claim 16 wherein said bushing thermally insulate said top end of said pin from a wall of said cavity in said base.

18. An apparatus for spatial control of temperature of a substrate comprising:

a temperature-controlled base having a top surface;

a ceramic plate having a heater bonded to an underside of the ceramic plate;

a first adhesive layer bonding said ceramic plate to the top surface of said temperature-controlled base; and

a layer of dielectric material bonded to a top surface of said ceramic plate with a second layer of adhesive, the layer of dielectric material forming an electrostatic clamping mechanism for supporting the substrate.

19. An electrical connector for a wafer support having a base, a bonding layer, a heater, and an electrostatic electrode, said electrical connection comprising:

a vertical spring loaded pin having a top end in contact with a bottom surface of the electrostatic electrode, said vertical spring loaded pin disposed in a cavity of said base, said bonding layer, and said heater; and

a bushing enclosing a portion of said top end of said pin, said bushing thermally coupled only to said heater and being non-electrically conductive.

20. The electrical connection of claim 19 further comprising a socket holding a bottom end of said pin.

21. The electrical connection of claim 20 further comprising a plastic insulator cover covering said socket and a portion of said pin, exposing said top end of said pin.

22. The electrical connection of claim 21 wherein said bushing thermally insulate said top end of said pin from a wall of said cavity in said base.

23. A method for controlling a temperature of a substrate comprising:

bonding a heater to a bottom surface of a metal plate, said heater electrically insulated from said bottom surface of said metal plate;

attaching said metal plate and said heater on a top surface of a temperature-controlled base with a layer of adhesive; and

depositing a layer of dielectric material on a top surface of said metal plate to form an electrostatic clamping mechanism, said layer of dielectric material for supporting the substrate.

24. The method of claim 23 further comprising machining down said top surface of said base flat to within about 0.0003".

25. The method of claim 23 wherein a surface dimension of said metal plate is substantially similar to the surface dimension of said temperature-controlled base.

26. The method of claim 23 wherein said metal plate has also a top surface, the top surface and bottom surfaces being substantially parallel to each other to within about 0.0005".

27. The method of claim 23 wherein said heater is a thin and flexible film.

28. The method of claim 23 wherein said heater includes one or more resistive heating elements.

29. The method of claim 23 further comprising forming a pattern layout on said metal plate with said resistive heating elements.

30. The method of claim 23 wherein said layer of adhesive includes a uniformly deposited mechanically flexible thermal insulator layer.

31. The method of claim 23 wherein said layer of adhesive includes a solid plate.

32. The method of claim 31 wherein said solid plate includes a top and bottom surface, said top and bottom surface being substantially parallel to each other to within 0.001".

33. The method of claim 31 wherein a thermal conductivity of said solid plate is based on the relative power levels employed by said heater and an external process.

34. The method of claim 32 further comprising bonding said solid plate on said top surface of said base with a mechanically flexible adhesive having a substantially high thermal conductivity.

35. The method of claim 32 further comprising bonding said solid plate to said bottom surface of said metal plate with a mechanically flexible adhesive having a substantially high thermal conductivity.

36. The method of claim 31 further comprising machining down a top surface of said metal plate flat to within about 0.0005" after said metal plate is attached on said top surface of said base.

37. A method for spatial control of temperature of a substrate comprising:

bonding a heater to a bottom surface of a ceramic plate;

attaching said ceramic plate and heater on a top surface of a temperature controlled base with an adhesive layer; and

depositing a layer of dielectric material on a top surface of said ceramic plate to form an electrostatic clamping mechanism, said layer of dielectric material for supporting the substrate.

38. A method for electrically connecting an electrical connector to an electrostatic electrode of a wafer support having a base, a bonding layer, and a heater, the method comprising:

contacting a top end of said electrical connector including a vertical spring loaded pin, with a bottom surface of the electrostatic electrode, said vertical spring loaded pin disposed in a cavity of said base, said bonding layer, and said heater; and

enclosing a portion of said top end of said pin with a bushing that is thermally coupled only to said heater and non-electrically conductive.

39. The method of claim 38 further comprising holding a bottom end of said pin with a socket.

40. The method of claim 39 further comprising covering said socket and a portion of said pin with a plastic insulator cover while exposing said top end of said pin.

41. The method of claim 40 further comprising thermally insulating said top end of said pin from a wall of said cavity in said base with said bushing.

42. An apparatus for controlling a spatial temperature of a substrate comprising:

means for bonding a heater to a bottom surface of a metal plate, said heater electrically insulated from said bottom surface of said metal plate;

means for attaching said metal plate and said heater on a top surface of a temperature controlled base with an adhesive layer; and

means for depositing a layer of dielectric material on a top surface of said metal plate to form an electrostatic clamping mechanism, said layer of dielectric material supporting the substrate.

43. An apparatus for controlling a spatial temperature of a substrate comprising:

means for bonding a heater bonded to a bottom surface of a ceramic plate;

means for attaching said ceramic plate and heater on a top surface of a temperature controlled base with an adhesive layer; and

means for embedding an electrode in said ceramic plate to form a part of an electrostatic clamping mechanism, said ceramic plate supporting the substrate.

44. An electrical connector for a wafer support having a base, a bonding layer, a heater, and an electrostatic electrode, said electrical connection comprising:

means for contacting a top end of said electrical connector including a vertical spring loaded pin, with a bottom surface of the electrostatic electrode, said vertical spring loaded pin disposed in a cavity of said base, said bonding layer, and said heater; and

means for enclosing a portion of said top end of said pin with a bushing that is thermally coupled only to said heater and non-electrically conductive.

45. A plasma etching system comprising:

a chamber having a support; and

a power supply,

wherein said support has:

a temperature controlled base having a top surface;

a metal plate having a heater thermally coupled to an underside of said metal plate, said heater electrically insulated from said metal plate, said power supply electrically coupled to said heater;

an adhesive layer bonding said metal plate and said heater on said top surface of said temperature controlled base; and

a layer of dielectric material deposited on said metal plate to form an electrostatic clamping mechanism, said layer of dielectric material for supporting the substrate.

46. The plasma etching system of claim 45 further comprising:

a temperature probe coupled to said metal plate; and

a feedback controller coupled to said temperature probe and said power supply.

47. The plasma etching system of claim 45 further comprising an electrical connector having:

a vertical spring loaded pin having a top end in contact with a bottom surface of said layer of dielectric material, said vertical spring loaded pin disposed in a cavity of said base, said first layer of adhesive layer, and said heater; and

a bushing enclosing a portion of said top end of said pin, said bushing thermally coupled only to said heater and being non-electrically conductive.

48. A plasma etching system comprising:

a chamber having a support; and

a power supply,

wherein said support has:

a temperature controlled base having a top surface;

a ceramic plate having a heater bonded to an underside of said ceramic plate, said power supply electrically coupled to said heater;

an adhesive layer bonding said ceramic plate and said heater to said top surface of said temperature controlled base; and

a layer of dielectric material deposited on said metal plate to form an electrostatic clamping mechanism, said layer of dielectric material for supporting the substrate.

49. The plasma etching system of claim 48 further comprising:

a temperature probe coupled to said metal plate; and

a feedback controller coupled to said temperature probe and said power supply.

50. The plasma etching system of claim 48 further comprising an electrical connector having:

a vertical spring loaded pin having a top end in contact with a bottom surface of said layer of dielectric material, said vertical spring loaded pin disposed in a cavity of said base, said first layer of adhesive layer, and said heater; and

a bushing enclosing a portion of said top end of said pin, said bushing thermally coupled only to said heater and being non-electrically conductive.